Tracking of Pair Production Events for GRETA

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One of the advantages of GRETA is its high photo-peak efficiency for high energy γ-rays (e.g. $E_\gamma \geq 10$ MeV) [1]. Above the threshold of 1.022 MeV, the probability of pair production increases as energy increases. At 10 MeV, this probability is about 60 % and therefore the pair-production events need to be identified with a high efficiency. A tracking algorithm has already been developed for Compton scattering events [2]. As the next step, we have developed a tracking algorithm for pair production events. In most cases, pair production occurs at the first interaction because the energy of γ-rays decreases rapidly as a Compton scattering sequence proceeds and there is a smaller probability for pair production after the first interaction. The pair of electron and positron produced by a 10-MeV γ-ray have short ranges of less than 6 mm in Ge. Therefore, the paths of electron and positron could be identified as a single interaction point with a high energy deposit of $E_\gamma - 1.022$ MeV. The annihilation of positron produces two 0.511-MeV γ-rays and each of them creates a cluster of interaction points. Therefore, the pattern of pair-production events can be characterized as a single high-energy point surrounded by low energy points.

A tracking algorithm has been developed by utilizing these characteristics. The first step of the algorithm is to select candidates of pair-production points based on the high energies deposited. In the second step, the two 0.511-MeV clusters are searched close to the high-energy point. The search and test of a 0.511-MeV cluster are done by using the Compton kinematics and conditions on the spatial distribution of points. If the two clusters are successfully found, all the cluster points and the high-energy point are assigned to a pair production event.

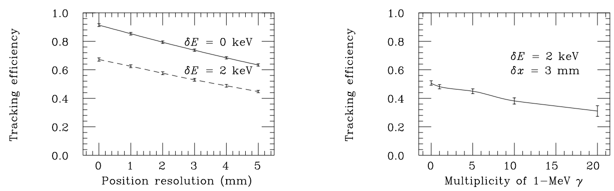

Figure 1: Left: Tracking efficiency for 10-MeV pair-production events as functions of energy and position resolutions. Right: Tracking efficiency as a function of multiplicity of background 1-MeV γ-rays.

The algorithm was tested using simulated data of interaction points generated by GEANT3. The detector consisted of a shell of Ge with 21 cm outer radius and 12 cm inner radius, which is a simplified model of a possible GRETA configuration. In each event, a 10-MeV γ-ray was launched from the center in coincidence with several 1-MeV γ-rays, which simulate background γ-rays. Figure 1 shows the tracking efficiency (ϵ_t) for pair events as functions of energy and position resolutions (δE and δx, respectively) and multiplicity of 1-MeV γ-rays (M_1). It can be seen that the efficiency decreases linearly as δx or M_1 increases. A preliminary result gives a value of $\epsilon_\mathrm{t} \sim 0.5$ at 10 MeV for $\delta E = 2$ keV and $\delta x = 3$ mm. Note that the photo-peak efficiency for pair events is the product of ϵ_t and full absorption efficiency ϵ_a (~ 0.7 at 10 MeV) for the Ge shell. The efficiency ϵ_t could be improved by modifying the algorithm to accept single-escape events.

References

[1] M.A. Deleplanque et al., NIM A430 (1999) 292.

[2] G.J. Schmid et al., NIM A430 (1999) 69.